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Constraints on fault dynamic weakening mechanisms from natural slip surfaces in carbonate faults

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Recent theoretical and experimental studies have proposed that fault lubrication (sliding friction coefficient $f < 0.2$) during earthquake propagation is due to thermally activated, dynamic weakening mechanisms (e.g. flash heating, thermal pressurization and nanopowder lubrication). Field-based observations from seismically active fault zones, combined with microstructural analysis of selected fault rock samples, may provide valuable constraints on the critical parameters controlling dynamic weakening of seismic faults (e.g. slip zone thickness, roughness, porosity/permeability and grain size and shape distributions).

We studied 11 fault segments of three well-exposed, active extensional fault systems in the central-northern Apennines of Italy: the Umbria, L'Aquila and Fucino Basin Fault systems. All the studied fault segments are located along a NW-SE oriented seismic belt which, in the last two centuries, has hosted moderate/large earthquakes ($5<M<7$).

Field studies show that most of the fault displacement is accommodated within the fault cores, which are a few to tens of meters thick and display a complex internal architecture of fault parallel domains made up of: fault breccias, fine to coarse grained matrix- and grain-supported cemented cataclasites and fault gouges. Within the fault cores, slip is further localized within narrow slip zones (<1 mm) often bounded on one side by a principal slip surface, which appears as a polished and striated plane. Slip localization in the fault cores has been observed at the boundary between the damaged host rock and the fault core rocks, between two different fault rock domains and also within homogeneous fault rock domains.

Preliminary field-based and microstructural observations from fault core slip zones show that they are a few mm to tens of mm thick, and display a complex internal structure comprised of juxtaposed layers of low porosity, coarse grained to ultra-fine grained cataclasites. Straight and sharp slip surfaces are often observed to form: 1) within the coarse and fine grained cataclasites and 2) at the boundary or within ultra-thin ultracataclasite layers (<50 microns), characterized by the presence of abundant nanoscale particles. The roughness of the slip zones ranges from asperities of a few mm, for the polished, striated and wavy slip surfaces developed within the coarse and fine grained cataclasites, to sub-micron asperity size, for the sharp and straight slip surfaces present within the thin ultracataclasite layers. Injected cataclasite and microstructures associated with fluidization processes have been observed within the fine and coarse grained cataclasite layers bounding the thin ultracataclasite layers.

Our preliminary field and microstructural observations suggest that slip zones observed in active carbonate faults are thin enough to promote the high temperatures required to trigger dynamic weakening mechanisms such as flash heating and thermal pressurization. However, flash heating processes may be inhibited when the size of the asperity contacts is too small, due to the large displacements and the high degree of shear localization (e.g. slip surfaces in the ultracataclasite layers). Alternative dynamic weakening mechanisms, for example the rolling friction of nanoparticles, may lubricate faults under these conditions.